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ACCRETIONARY WEDGE AND ADJACENT ABYSSAL PLAIN OFF OREGON AND WASHINGTON

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Investigations

The overall objective of this project is to characterize and determine the timing of deformational events in the subducting Juan de Fuca plate (abyssal plain) and deformation front (accretionary wedge) of the Cascadia convergence zone off Oregon and Washington. A neotectonic map was constructed of the subducting oceanic plate, accretionary wedge, and adjacent continental shelf basins off central and northern Oregon to identify the styles and areal extent of deformation. We are trying to identify and date discrete deformational events and relate them to the distribution of earthquakes on the subducting oceanic plate and in the subduction zone.

Results

Active Fault Zones and Segment Boundaries: Abyssal Plain

Sidescan sonar surveys, SeaBeam bathymetry, single/multichannel seismic records, and ALVIN submersible observations show surficial and basement faults in the Cascadia subduction zone. At least three major left-lateral strike-slip faults (A-C) occur on the abyssal plain and extend into the accretionary wedge and forearc basins of the continental shelf off central and northern Oregon (Figs. 1, 2; Goldfinger et al., 1990, 1991; Mackay et al., 1991). These faults are possible segment boundaries (Goldfinger et al., 1990) which strike uniformly between 282° and 298°.

Wecoma fault (Fault A), a prominent linear fault scarp oriented 295°, extends at least 17 km across the abyssal plain from 45°10'N (Fig. 1A,B; Appelgate, et al., 1989; Goldfinger et al., 1989, 1990). High-resolution SeaMARC-IA sidescan sonar images display along-strike reversals in vertical separation and a very straight trace, characteristic of strike-slip faults. Seismic reflection and magnetics data show 75-100 m of vertical basement separation across the fault. Using seafloor channels and a ridge that are crosscut by the fault, we calculate between 300 and 2500 m of left-lateral separation along the fault (Appelgate et al., 1991). Structural and stratigraphic constraints on the offset of the late Pleistocene channel shown in figure 1B result in a Holocene slip-rate of between 5 and 11 mm/yr (Appelgate et al., 1991; Goldfinger et al., 1991). Isopach maps of the pre-faulting abyssal plain sediments surrounding Fault A indicate these acoustic units are offset 5-6 km by the fault (Goldfinger et al., 1991). Faulting began 1.0 to 0.6 Ma, which gives an average rate of slip of 5-9 mm/yr, similar to the Holocene rate. Reconstruction of erosional events within the channel that crosses this fault (Fig. 1B), using carbon-14 dating of sandy turbidites cored within the channel, will further constrain the latest Pleistocene/Holocene rate of slip.

Fault A can be traced eastward onto the initial deformation front (marginal ridge) of the accretionary wedge (Fig. 1A, structural reentrant), where it is expressed as a set of splays that breach the initial thrust ridge and adjacent structural basin to the east. Southeasterly-trending gullies (fault-controlled zones imaged in sidescan) along the seaward face of the deformation front contain live chemosynthetic-type clams and tube worms as well as methane-derived carbonate slabs and crusts, which are evidence of both past and present fluid venting along the fault zone. *In situ* displacements of the strata and numerous structures (slickensides and mullions, fractured rocks, and veins/webs) show the extensive disruption and fluid movement through the sandstones and mudstones comprising the accretionary wedge. All data indicate that the strike-slip fault is presently active where it cuts across the main deformation front. Multichannel (144 channels) seismic records made across the fault on the abyssal plain show stratigraphic displacement throughout the sedimentary section and display flower structures typical of strike-slip faults. Small offsets of the basaltic basement appear to be local and may be due to the strike-slip juxtaposition of local variations in the basement surface. Deep seismic reflections in abyssal-plain sediments show vertical separation, which also implies basement involvement. Faults A and B are associated with north-plunging, anticlines in the abyssal plain a few kilometers seaward of their intersections with the deformation front (Figs. 1A,2; Goldfinger et al., 1990). The southern flanks of both anticlinal structures are truncated by splays of the strike-slip faults in complex positive flower structures. Methane-derived fluids are venting along the anticlinal structures and faults, indicating they are active (Kulm et al., 1989).

Faults B and C offset the main deformation front in a left-lateral sense (Figs. 1A,2). Fault B occurs at a major change in vergence direction of the thrust sequences from seaward vergence to the south and landward vergence to the north. This vergence change occurs along the fault as it extends eastward into the accretionary wedge, implying that the interaction of the strike-slip fault with the accretionary wedge structures may induce changes in vergence direction. This is further supported by seismic interpretation of the intersection of fault A with the deformation front. In the zone between the splays of fault A, a local vergence change from landward to seaward occurs (Fig. 1A).

Catastrophic Events: Great Earthquakes

Turbidity-current events have been used to demonstrate the near-term hazard of great earthquakes on the Cascadia subduction zone off Oregon and Washington (Adams, 1990). To further evaluate this hazard, several gravity cores were collected adjacent to active faults on the abyssal plain and at the foot of headless submarine canyons which cut into the deformation front (Fig. 1A). The cores contain from 1 to 12 turbidites. High-resolution radiolarian biostratigraphy and radiocarbon dating indicate that the sediments in all cores are younger than 15,000 yrs. B.P (i.e., post-glacial). Radiocarbon dating of a 2.5 m-long turbidite-bearing core (W7905A-136GC) on the abyssal plain produced ages of 6,580 ±110 and 10,460 ±130 yrs B.P. (before 1950 A.D.) at stratigraphic intervals of 139 cm and 227 cm, respectively. Six turbidites occur in the upper interval and indicate a recurrence interval of one turbidite every 1,096 yrs and five turbidites in the lower interval indicate one turbidite every 776 yrs on the average. A total of 12 turbidites occur in this core. This core and three others in the vicinity that contain turbidites are located in the middle of a 580 km-long gap (Adams, 1990) between the apparently synchronous deposition of turbidites in Cascadia deep-sea channel and Astoria Canyon, near the Columbia River, and turbidite deposition to the south on the abyssal plain near Cape Blanco.

We have obtained a preliminary date for the time of collapse of one of the largest slumps found along the initial deformation front off northern Oregon. The debris pile from the 32 km^3 slump (Fig. 1A, labeled "10-15 ka slump") rests upon a seismic reflector on the abyssal plain that is essentially coincident with the seafloor north and south of the pile, with no onlap from turbidite sedimentation. A core 1.55 m-long taken on top of this debris pile contains only hemipelagic sediment (Fig. 1A, labeled "core"). Radiolarian biostratigraphy indicates an age younger than 15,000 years B.P. for the oldest sediment in this core. A calibrated radiocarbon date of 10,300

±150 yrs B.P. (before 1950 A.D.) was obtained near the bottom of this core to confirm the biostratigraphic age. Using Holocene hemipelagic and Pleistocene turbidite sedimentation rates and high-resolution 3.5 kHz and multichannel seismic records across the debris pile, we estimate an age of 10,000-24,000 yrs B.P. for the slump. If this catastrophic slump was associated with a large earthquake, it occurred during latest Pleistocene time.

Active Fault Zones: Accretionary Wedge and Forearc Basins

Faults A and B can be traced 120 km landward (southeast) of the initial deformation front, across the continental slope (accretionary wedge) and onto the inner continental shelf (Fig. 2). They both displace strata of probable late Pleistocene to Holocene age on the shelf, and project onshore near Cape Foulweather and Alsea Bay, respectively (Goldfinger et al., 1990). Faults C, D, and the other four significant faults presently under investigation off central and northern Oregon (44°-46°N) also cut strata of the same age and are traced onto the middle to inner continental shelf. These faults are recognized as strike-slip structures on the basis of offset fold axes, sigmoidal bending of fold axes, linear scarps, and offset of the shelf break and slope terrace break in map view. Mismatched stratigraphy, apparent reverse drag, and truncation or repetition of structures characterize the seismic sections.

Extensive folding of late Pleistocene to Pliocene sediments also occurs on the upper slope and shelf to within a few kilometers of the coast. Two styles of folds are present: fault-parallel folds, which are found in close proximity to the throughgoing strike-slip faults, and folds striking 300° to 340°, averaging about 310°-320°. The fault-parallel folds are apparently related to a convergent component across the strike-slip faults, a relation observed in some of the seismic-reflection data. The NW-striking folds are close to being normal to the plate convergence direction (055°-071° Riddihough, 1984; DeMets et al., 1990), and are compatible with the regional tectonic setting of oblique plate convergence.

The age of deformation related to these structures is somewhat problematic in the inshore areas. However, some of the folds and faults deform the sea floor in water depths between 30 and 100 m., and many others show stratigraphic evidence of growth in the uppermost reflectors. A high percentage of the folds in figure 2 are active on the basis of scarps formed by flexural-slip faulting during growth of the structures and stratigraphic thickening or thinning in fold axes. Flexural-slip faulting is very common on the Oregon shelf and is well documented onshore in the South Slough syncline of the Coos Bay area (McInelly and Kelsey, 1990; Fig. 2, see inset for location). The observed flexural-slip-fault scarps in relatively shallow water indicate activity on these faults subsequent to Holocene sea-level rise, and therefore Holocene downwarping of the synclines. Flexural-slip fault scarps presently offset the sea floor in water depths as shallow as 60 m and are well-preserved despite this wave action. These scarps are developed in strata of probable Pleistocene and Holocene age, not older rocks in which erosional hogbacks might develop. Most eustatic sea level curves indicate that the last glacial lowstand would have flooded these fault scarps about 8,000 to 10,000 years ago, after which the scarps would have passed through the surf zone and would have been smoothed by wave-base erosion. We conclude that these scarps must post-date their residence time in the surf zone at about 8,000 to 10,000 years ago.

A significant result of the mapping of these offshore and nearshore folds and faults has been the discovery that many active synclines, both fault-parallel and otherwise, project onshore into coastal bays, some of which show evidence of coseismic subsidence of marshes. At the present time, Nehalem, Tillamook, Netarts, Siletz, Nestucca, Yaquina, Alsea, and Coos bays all appear to be sites of active downwarping in synclinal axes (Fig. 2). Additionally, several of the fold axes and faults show a good correlation with previously mapped faults and folds onshore, although the ages of the onshore structures are not independently known. A good example of this correlation occurs at Tillamook Bay, where an onshore left-lateral fault mapped by Niem and

Niem (1985) lies on trend and has the same sense of vertical and horizontal displacement as an active left-lateral fault mapped on the shelf to within 4.6 km of the coast. Downwarping of Pleistocene terrace deposits at Yaquina and Siletz Bays supports a correlation between active offshore synclines and some of Oregon's coastal bays

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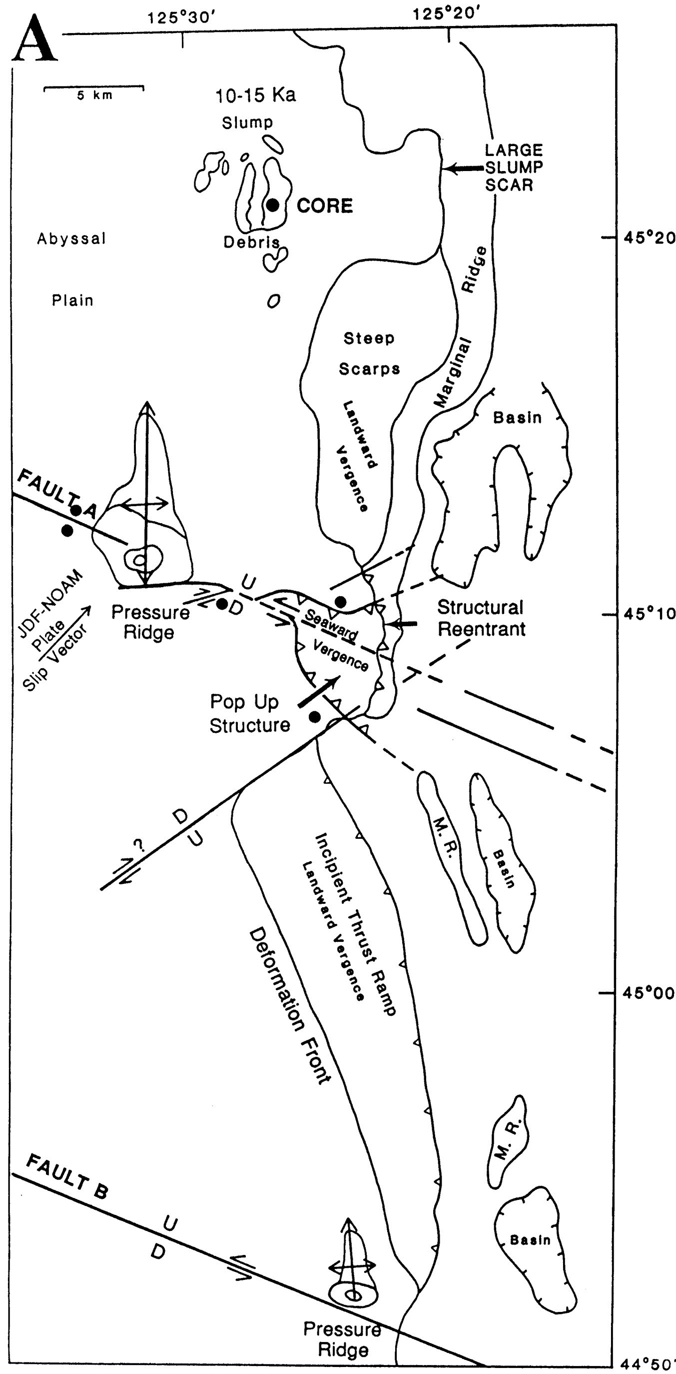

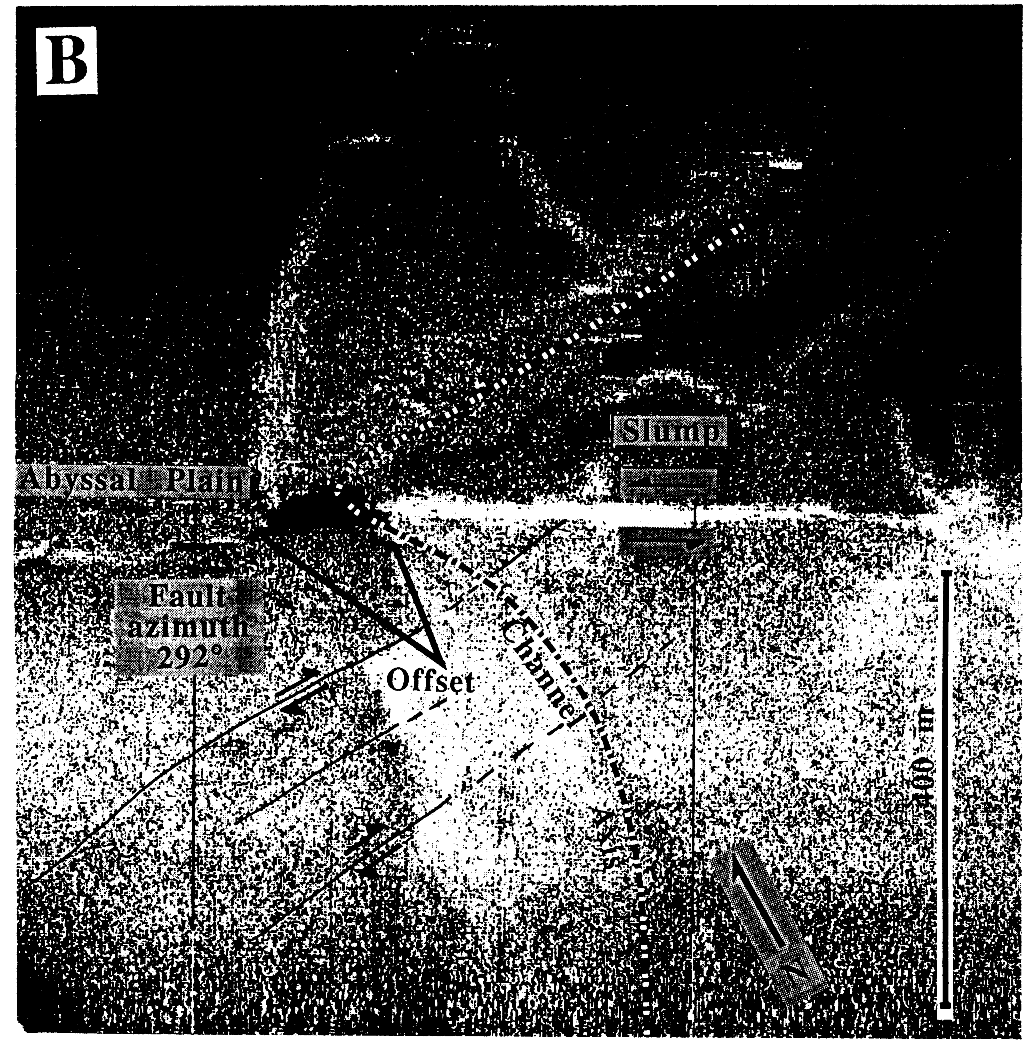

Figure. 1 (A) Morphology and structure of lower continental slope and abyssal plain off central and northern Oregon. Large slump scar and debris pile at top of map. Cores indicated by solid dot. See text for discussion and neotectonic map for structural context. (B) High resolution SeaMARC-1A sidescan sonar image of Fault A offsetting a late Pleistocene distributary channel on the southeastern Astoria submarine fan. Light tones represent high backscatter, insonification is from the south. Vertical scarps are the result of strike-slip juxtaposition of irregular sea-floor. Older secondary right-lateral faults are outlined for clarity. See boxed area on Fig. 1 for location.

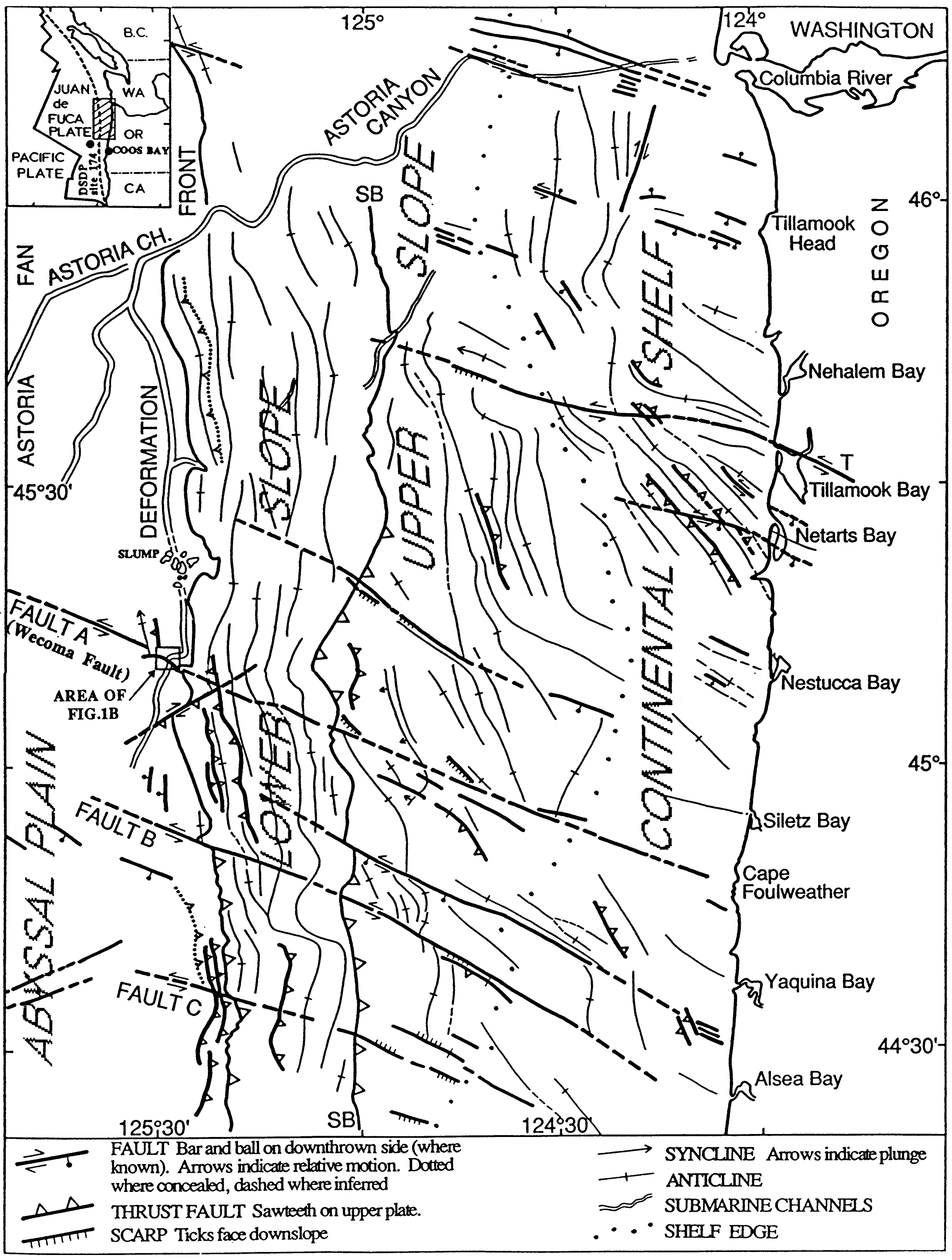

Figure 2. Structure map of the northern and central Oregon margin. Most structures cut or deform the sea floor. The deformation front is a thrust fault south of Fault B, and the base of a seaward dipping ramp north of Fault B. SB = slope break; T = Tillamook Bay fault. See text and legend for explanation.